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# 입제비료의 흡습과 송풍식 살포기에서의 비산특성

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# Moisture Absorption of Granular Fertilizer and Its Distribution Characteristic in a Pneumatic Applicator

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Abstract

The characteristic of moisture absorption of granular fertilizer was measured at several different opening sizes on the top cover of a hopper in a humid weather. The size of the opening was to represent the degree of looseness of sealing of the top cover of the hopper. The application distribution was characterized by the scattering distance of granular fertilizer with different degree of moisture absorption in a pneumatic granular fertilizer applicator. The moisture absorption rates were 12.92 and 12.26 mg of moisture an hour for one gram of each granular fertilizers of NPK 22-12-12 and 21-17-17, respectively. The moisture absorption increased linearly as the opening size increased. The median value of the scattering distance distribution decreased with time of absorption, however, it decreased very slowly after three hours of absorption.

**Keywords :** Variable rate application, Moisture absorption, Pneumatic granular applicator, scattering distance, granular fertilizer

## 1. INTRODUCTION

Precision farming has been a popular topic of research in agriculture, especially on variable rate technology (VRT) for site specific prescription and application of pesticides, herbicides, and fertilizers to minimize the excess amount of these chemicals to the field. Its goal can be summarized as less pollution and cost effective farming while keeping productivity high. With technological advances from number of researches on this topic, precision farming is now a common practice on many U.S. farms (Fulton et al., 2001). There have been numbers of researches on the precision farming in Korea including global positioning system (GPS), geographic information system software (GIS), and VRT. A pneumatic variable rate application system was developed for granular fertilizer (Sohn et al., 2004, Seo et al., 2004) and some input parameters were investigated, which could determine the application uniformity of granular fertilizer (Kim et al., 2004).

Granular fertilizer is the most common type of fertilizer available in Korea and usual method of application is spreading by hand for small size fields and using spinner spreader or power dusters for large fields. Despite possible variation in soil fertility, amount of fertilizer per unit area is recommended for several kinds of crops and soils by the extension service of the Rural Development Administration

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of Korea. And even worse, most of farmers were reported applying more fertilizer than that of recommended expecting higher productivity. This excessive amount could be based on the farmer's experience from years of observation of trial and error method over crop yield and amount of fertilizer input needed for their specific condition of the field.

Application uniformity is important for both variable and field averaged constant rate application. Application distribution of granular fertilizer is determined by physical properties of the fertilizer along with the structural and operational characteristics of the applicator. Typical physical characteristics of concern are true and bulk density, shape, and size distribution of fertilizer. The structural and operational conditions can be determined for the best application uniformity of the applicator once the physical properties of the fertilizer of concern are determined. There are two kinds of granular fertilizer in common use; NPK compound fertilizer (Shinsedae, 22-12-12: NPK and Super21, 21-17-17: NPK). These fertilizers have hygroscopic property. It tends to absorb moisture at humid weather, which changes the density of the granular fertilizer and then its application distribution. Hopper of granular applicator in Korea is usually left open or covered loosely with its top cover rather than covered tightly. This may cause moisture absorption and density change during fertilizer application at humid weather.

The objectives of this study are 1) to measure the characteristic of moisture absorption of granular fertilizer at several different opening sizes on the top cover of a model hopper in a humid weather condition and 2) to characterize application distribution by the scattering distance of granular fertilizer with different degrees of moisture absorption by a pneumatic granular fertilizer applicator.

## 2. MATERIALS AND METHODS

### A. Particle size distribution

Two brands of granular fertilizers were used for the experiment; Shinsedae (NPK: 22-12-12, Namhae Chemical Co. Ltd., Seoul, Korea) and Super21 (NPK: 21-17-17, Namhae Chemical Co. LTD., Seoul, Korea). Particle size distribution was measured using 500 g of fertilizer placed in a Tyler sieve series according to the method described in ASAE standard 319.2. The Tyler sieve opening sizes were 4.76, 3.36, 2.38, 1.68, 1.19, 0.84 mm. The sieve series were shaken gently for five minutes vertically and horizontally. Weights of sieves were measured to determine the mass of fertilizers on each sieve. The fertilizer particle size distribution was 1.43, 11.27, 69.15, 14.79, 3.21, 0.15% for Super21 and 1.08, 11.44, 68.47, 17.34, 1.64, 0.03% for Shinsedae on each sieve opening sizes of 4.76 to 0.84 mm, respectively. Bulk and particle density was 901 and 1,320 kg/m$^3$ for Super 21 and 781 and 1,410 kg/m$^3$ for Shinsedae, respectively.

Geometric mean length $X_{gm}$ and standard deviation $S_{gm}$ of granular fertilizer was determined by equation (1), (2), and (3) from measurements of particle size distribution.

$$X_{gm} = \log^{-1}\frac{\sum(M_i \log \overline{X_i})}{\sum M_i} \quad (1)$$

$$\overline{Xi} = (X_i \times X_{i-1})^{1/2} \quad (2)$$

Where $\overline{Xi}$ = geometric mean length of particle on the $i$th sieve, mm

$X_i$ = mesh opening size of ith sieve, mm

$M_i$ = mass on the ith sieve, g

$$S_{gm} = \log^{-1}\left[\frac{\sum M_i(\log \overline{X_i} - \log X_{gm})^2}{\sum M_i}\right]^{1/2} \quad (3)$$

Geometric mean length and its standard deviation were 2.75 mm and 1.49 for Super21 and 2.73 mm and 1.50 for Shinsedae, respectively.

### B. Moisture absorption of granular fertilizer

Top dressing for paddy field is usually applied in early August in Korea and its weather condition is humid. For example typical weather condition at Suwon is 30°C and 80% RH (Korea Meteorological Administration, 2005). The weather condition for moisture absorption was set to 35°C and 85%RH for possible severe condition in August. Moisture absorption at this weather condition was simulated in a constant temperature/humidity chamber (DS-543, DASOL SCIENTIFIC CO., Hwasung, Korea),

Granular fertilizer was screened into three levels of size using a series of sieves with opening size 4.76, 3.36, 2.38, 1.68 mm by shaking the sieves gently vertically and horizontally. Fertilizer between sieves opening size 4.76 and 3.36 mm was named as No. 6, 3.36 and 2.38 mm as No. 8, and 2.38 and 1.68 mm as No. 12. Granules of the three levels of size takes 97% of the total amount and was intended to determine the effects of size of voids among granules on hygroscopic properties of granular fertilizers.

Moisture absorption of granular fertilizer was measured every one hour for 50 g of unscreened granules on a Petri dish for 11 hours in a constant temperature and humidity chamber at 35°C and 85%RH. And moisture absorption of each 50 g of No 6, 8, and 12 was measured to determine the effects of granule size on the rate of moisture absorption at the same condition as the unscreened.

Plastic rectangular containers with a cover lid and rubber gasket were used as model hopper of a fertilizer applicator and the lids have different number of holes to represent the degree of looseness of the top lid of the hopper (155 mm (W) x 220 mm (D) x 110 mm (H)). A sheet of stainless screen was located on the bottom of sample fertilizer to drain the dissolved fertilizer by the moisture absorption as shown in Fig. 1. The hole is 1 cm diameter and number of holes was 1, 3, 6, and 12. The size of opening on the top lid is shown in Table 1. Each 200 g of different sized fertilizer every one hour in the constant temperature/humidity chamber at 35°C and 85%RH for 12 hours.

**Table 1** Opening sizes of model hopper lids

| | hole1 | hole3 | hole6 | hole12 | No lid |
|---|---|---|---|---|---|
| Opening size (cm$^2$) | 0.7854 | 2.3562 | 4.7124 | 9.4248 | 341.00 |
| Opening degree (%) | 0.23 | 0.69 | 1.38 | 2.76 | 100 |

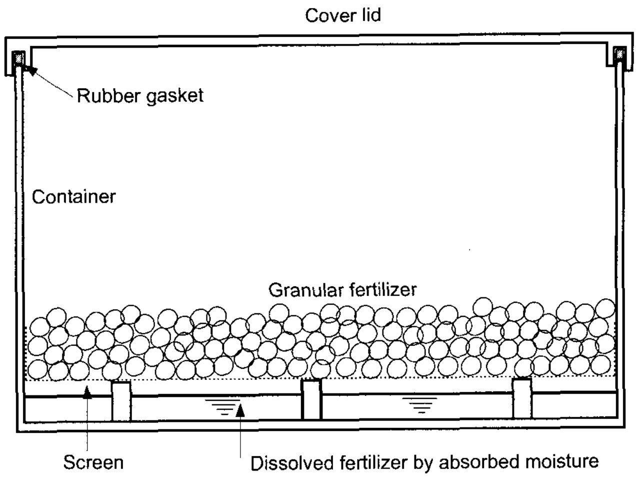


**Fig. 1** Model hopper for moisture absorption experiment.

## C. Application distribution measurement

An experimental pneumatic granular fertilizer applicator is shown in Fig. 2. It consisted of a transparent acrylic boom tube with 54 mm ID and 1 m long, air blower with air speed of 50 m/s at the tube inlet and 20 m/s at the outlet, and patternator. The boom tube was located 1.5 m high from the ground and 1 m apart from the patternator. The patternator is 0.3 m high, 3.6 m long and has 12 blocks of partition of same size.

Application distribution was measured for granular fertilizer of 200 g with different degrees of moisture absorption. Scattering distance was measured with granular fertilizer which absorbed moisture with top lid opened in the constant temperature/humidity chamber at 35°C and 85%RH for one to 12 hours.

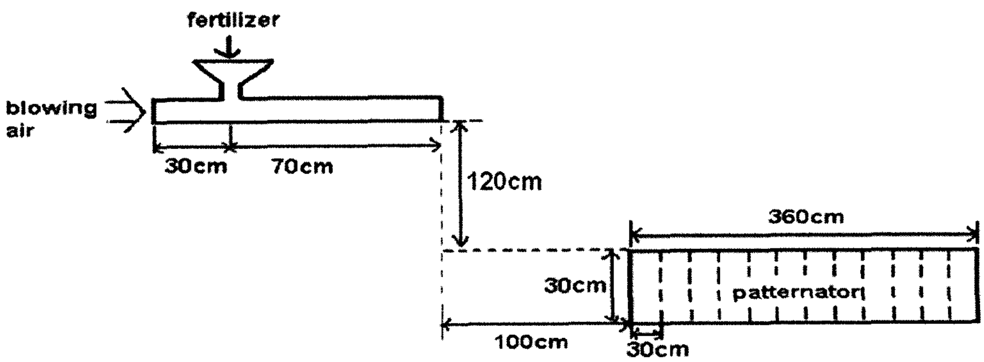


**Fig. 2** Experimental pneumatic applicator and patternator (not to scale).

## 3. Results and Discussion

### A. Moisture absorption of granular fertilizers

Granular fertilizer is hygroscopic and forms a cake at humid weather; especially when package sealing is once opened or broken for a long time. This may cause trouble with the VAT applicator to apply proper amount of fertilizer with the operation condition set with normal fertilizer properties such as density and size. Granular fertilizer applicator in Korea is not equipped with such crushers to break cake of fertilizer into small pieces of granule as in United States. Figure 3 shows the moisture absorption of each 50 g of two brands of unscreened granular fertilizers (mg of moisture absorption per g of fertilizer; $mg_m/g_f$) for 11 hours. Each point is an average value of three measurements. The moisture absorption increased linearly with time in the constant temperature/humidity chamber. Shinsedae absorbed 12.92 $mg_m/g_f$ and Super21 12.26 $mg_m/g_f$ an hour as in regression equations (4) and (5).

$$Y_{sp} = 1.92 + 12.26X,\ R^2 = 0.9995 \quad (4)$$

$$Y_{ss} = 0.25 + 12.92X,\ R^2 = 0.9997 \quad (5)$$

Where $Y_{sp}$ = moisture absorption of Super21, $mg_m/g_f$
$Y_{ss}$ = moisture absorption of Shinsedae, $mg_m/g_f$
X = time of moisture absorption, hour

Figure 4 and 5 show results of moisture absorption of granular fertilizers screened by size. Each point of Fig 5 and 6 is an average value of three measurements. The total surface area of granules might be a key factor which determines the rate of moisture absorption. Smaller sized granules with same weight have larger surface area than that of larger sized granules while the size of void among small granules is smaller than larger sized granules. Brand Shinsedae absorbed more moisture as granule size decreased as shown in Fig. 4. The rate of moisture absorption increased slightly with decrease of granule size from 11.76 to 12.33 $mg_m/g_f$ an hour as in regression equations (6), (7), and (8). However, there was no distinct trend in moisture absorption with granule size for Super21 as shown in Fig. 5.

$$Y_{ss} = -0.12 + 11.76X,\ R^2 = 0.9995 \text{ for No.6,} \quad (6)$$

$$Y_{ss} = -0.54 + 12.31X,\ R^2 = 0.9998 \text{ for No.8,} \quad (7)$$

$$Y_{ss} = -3.65 + 12.33X,\ R^2 = 0.9989 \text{ for No.12,} \quad (8)$$

Where $Y_{ss}$ = moisture absorption of Shinsedae, $mg_m/g_f \cdot hr$
X = time of moisture absorption, hour

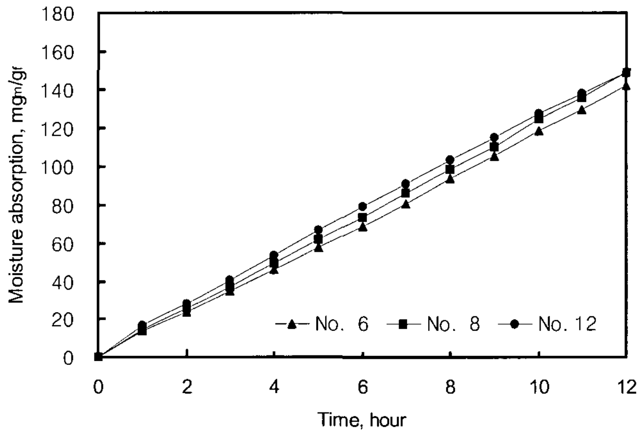

**Fig. 4** Moisture absorption of granular fertilizer (Shinsedae) with no cover lid.

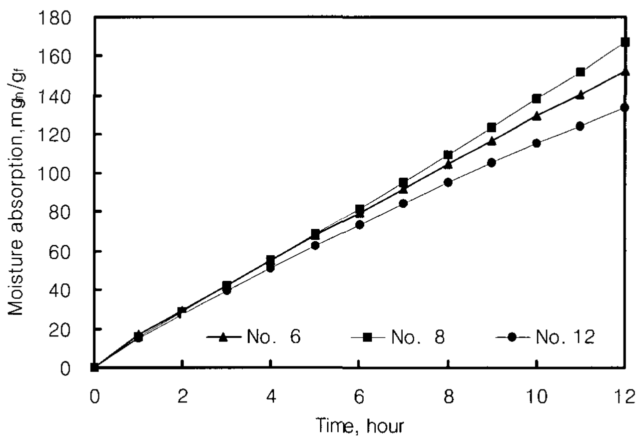

**Fig. 5** Moisture absorption of granular fertilizer (Super21) with no cover lid.

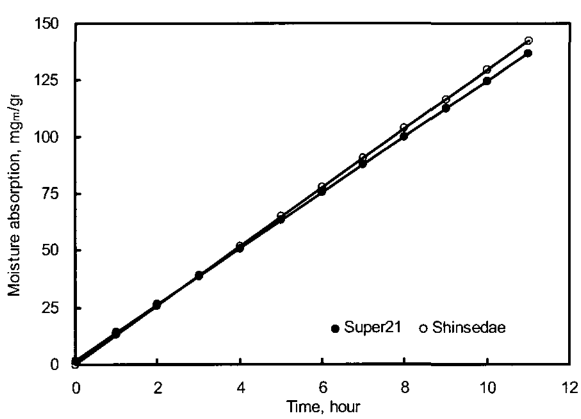

**Fig. 3** Moisture absorption of granular fertilizer with no cover lid.

Moisture absorption rate was 12.92 $mg_m/g_f \cdot hr$ for unscreened Shinsedae, which is slightly greater than that of granules screened by size (No. 6, 8, and 12). This can be described as the effect of increased total surface area of granules. However, brand Super21 showed no distinct effects of granule size on the rate of moisture absorption as shown in Fig. 5. The rates of moisture absorption for No. 6, 8, and 12 were 12.56, 13.75, and 11.08 $mg_m/g_f$ an hour as in regression equations (9), (10), and (11). Moisture absorption rate of No. 12 of Super 21 was 11.08 mgm/gf·hr, which was smaller than 12.26 mgm/gf·hr of unscreened granules on size while moisture absorption rate of No. 6 and 8 increased with decreased granule size. This could be described as the deviation of uneven composition of composite granular fertilizer from the size screening process. Another reason could be described as the change of effective surface area of granules exposed to the humid air as the moisture absorption proceeded. Smaller granules have more surface area exposed to the humid air. And then absorbs more moisture than bigger sized granules with the same weight. However, once granules start absorbing moisture, surface water forms around the granules and the void among granules decreases. And then the effective total surface area of granules decrease more than bigger sized granules. Shape of hoppers would be better have smaller top surface area for small sized granules or granules with small void among granules, since top surface area would be the driving force of absorbing moisture once air passage though voids blocked with dissolved fertilizer.

$$Y_{sp} = 3.66 + 12.56X,\ R^2 = 0.9993 \text{ for No. 6,} \quad (9)$$

$$Y_{sp} = 0.40 + 13.75X,\ R^2 = 0.9996 \text{ for No. 8,} \quad (10)$$

$$Y_{sp} = 4.84 + 11.08X,\ R^2 = 0.9971 \text{ for No. 6,} \quad (11)$$

Where $Y_{sp}$ = moisture absorption of Super21, $mg_m/g_f \cdot hr$
X = time of moisture absorption, hour

Moisture absorption in a model hopper with different cover opening sizes.

Moisture absorption rate was measured at different opening sizes of the cover lid of the model hopper and the results were shown in Fig. 6. The moisture absorption rate increased as opening size increased. The hopper of granular fertilizer applicator is usually left open in Korea during application. Just covering the hopper top could reduce moisture absorption effectively as shown in Fig. 6 despite the hopper would be empty in less than one hour before it absorbs considerable amount of moisture during fertilizer application. However, the moisture absorption of granular fertilizer would be a problem when there is fertilizer left in the hopper for a long time after the application. Tight cover sealing would reduce the density increase of granules from moisture absorption at humid weather and then could keep the uniformity of application with VAT.

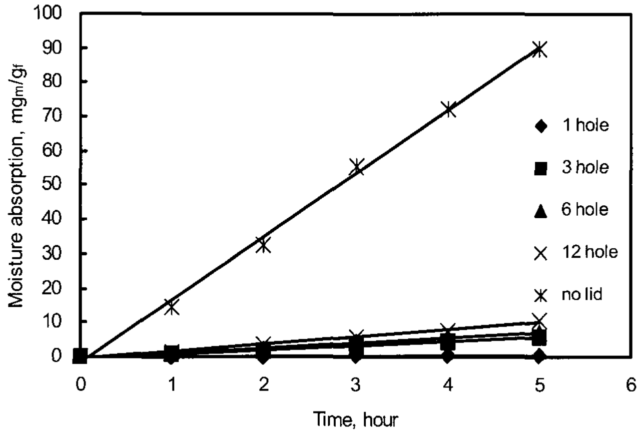


**Fig. 6** Moisture absorption of granular fertilizer at different cover openings.

## B. Application distribution

Figure 7 shows scattering patterns of fertilizers with different degree of moisture absorption in the constant temperature/humidity chamber. Scattering distance decreased as the moisture absorption increased with time; however, it showed no clear difference after three hours of absorption

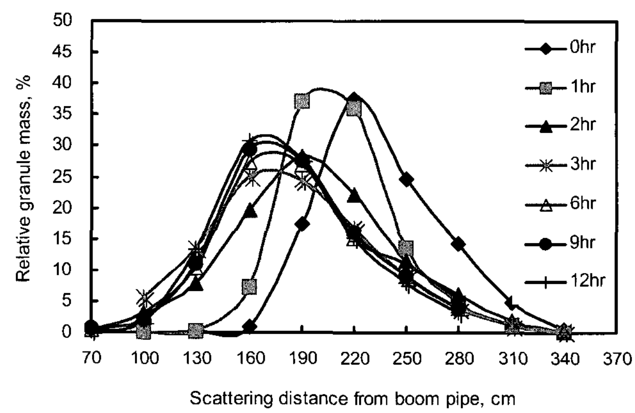


**Fig. 7** Spread pattern at different moisture absorption level.

as shown in Fig. 8.

Mode of scattering distance curve decreased with time as shown in Fig. 7 and 8. The dissolved fertilizer started dripping though the screen on the bottom of the plastic container after three hours of moisture absorption (Fig. 9). Each granule can hold some amount of dissolved fertilizer on its surface, which is the amount of moisture absorbed by the granular fertilizer for three hours in a 35°C and 85%RH humid air. After three hours from the start of absorption of moisture, further moisture absorption causes dripping from its surface and keeps its density constant to some degree. The granular fertilizer in a hopper would have rather constant distribution characteristics on a pneumatic applicator after three hours of moisture absorption at this humid weather (35°C and 85% RH). The applicator could be set to this distribution characteristic to get the prescribed amount of fertilizer accurately when this much of absorption happens before it forms a cake of fertilizer.

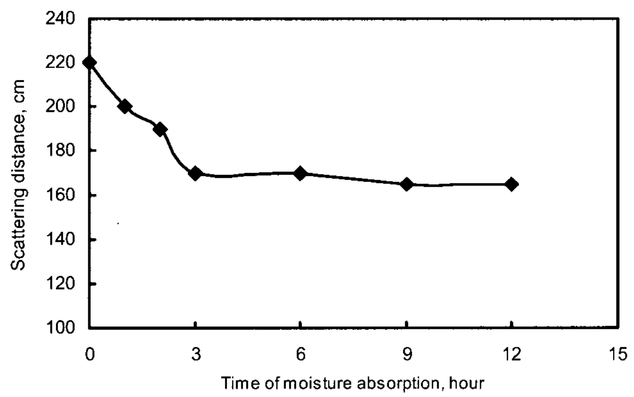


**Fig. 8** Mod of scattering distance and moisture absorption time.

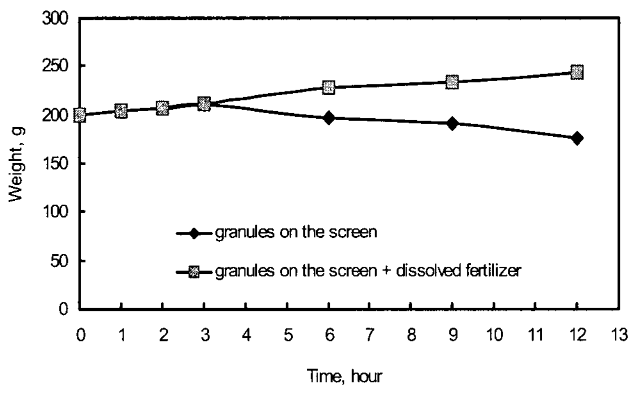


**Fig. 9** Weight change with time for granules on the screen and dissolved fertilizer.

## 4. CONCLUSION

Moisture absorption characteristic was measured for the granular fertilizer of two popular brands Super21 and Shinsedae at the humid weather condition of 35°C and 85%RH. The moisture absorption rates were 12.26 and 12.92 mg an hour for one gram of Super21 and Shinsedae, respectively. The effects were also measured for granule size and looseness of sealing of hopper cover on moisture absorption. The moisture absorption rate increased from 11.76 to 12.33 $mg_m/g_f \cdot hr$ as the size of granule decreased from No. 6 to 12 for Shinsedae. However, the moisture absorption rate was in the range of 11.08 to 13.75 $mg_m/ g_f \cdot hr$ with no explicit relation with granule size. The moisture absorption rate increased linearly with the opening size on the hopper lid. It has shown that just covering hopper top loosely would decrease the moist absorption considerably and tight sealing would be the best,

Scattering distance decreased as the moisture absorption increased with time; however, it showed no clear difference after three hours of moisture absorption with top lid opened at the weather condition of 35°C and 85%RH.

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